Report on the Accident to Airbus A320-211 Aircraft in Warsaw

on 14 September 1993

Main Commission Aircraft Accident Investigation Warsaw

Synopsis

DLH 2904 flight from Frankfurt to Warsaw progressed normally until Warsaw Okęcie TWR warned the crew that windshear existed on approach to RWY 11, as reported by DLH 5764, that had just landed. According to Flight Manual instructions, the PF used increased approach speed and with this speed touched down on RWY 11 in Okęcie aerodrome. Very light contact of the runway surface with the landing gear and lack of compression of the left landing gear leg to the extent understood by the aircraft computer as the actual landing resulted in delayed deployment of spoilers and thrust reversers. Delay was about 9 seconds. Thus, the braking commenced with delay and in the condition of heavy rain and strong tailwind (storm front passed through the aerodrome area at that time) aircraft did not stop on the runway.

In effect of the crash one crew member and one of the passengers lost their lives. The aircraft sustained damage caused by fire.

1. Factual information

1.1 History of the flight

An aircraft of type Airbus A320-211 serial number 105 with the markings D-AIPN operated by Deutsche Lufthansa performed regular scheduled flights. The planned route was: Frankfurt - Barcelona - Frankfurt - Warsaw - Frankfurt. The cockpit crew consisted of:

in the left seat: captain-pilot, subject to check, as pilot flying PF,

in the right seat: captain-pilot instructor in command of the aircraft, checking PF, himself as pilot not flying PNF

The legs Frankfurt - Barcelona - Frankfurt were performed uneventfully. Flight DLH 2904 from Frankfurt to Warsaw departed at 14:27 UTC. Cruise over the territory of Poland progressed at FL330. In the period 15:08:07 - 15:11:58 crew listened a few times to ATIS Warsaw and received the information UNIFORM. At 15:14:59, the crew asked ATC Warsaw for descent and was cleared to FL 190. At 15:19:12, Warsaw told the flight to continue directly to VOR WAR. At 15:21:09, the crew reported FL190 and was told to keep this level. At 15:22:50, ATC Warsaw told DLH 2904 to change over to contact APP on 128.8 MHz.

After establishing the contact with APP DLH 2904, was cleared to descend to FL50 and at 15:25:17, was commanded to descend to 950 metres on QFE 984 and vectored to intercept ILS on RWY 11. At 15:30:46, DLH 2904 reported stabilized status and was told to continue approach as Number 1 and to contact TWR on 121.6 MHz. After establishing contact TWR called: "LUFTHANSA 2-9-0-4, CONTINUE I-L-S APPROACH, CALL ME OUTER MARKER, WIND 1-6-0 DEGREES, 2-5 KILOMETERS PER HOUR AND BEFORE YOUR LANDING IT WAS REPORTED WINDSHEAR ON THE FINAL RUNWAY 1-1." DLH 2904 replied: "

ROGER, THAT'S UNDERSTOOD, I CALL YOU OUTER MARKER." At that time, the aircraft passed the altitude of about 2800 feet and kept airspeed recorded as CAS = 163 kts, while GS was 180 kts.

At 15:31:26, JET AVIATION 101, which had just landed, called: "WARSAW TOWER, GOOD EVENING, JETAVIATION 1-0-1 IS VACATING RUNWAY 1-1 ON TAXIWAY E-0, FOR INFORMATION WE HAD SEVERE WINDSHEAR ON FINAL."At 15:32:12, TWR called: "LUFTHANSA 2-9-0-4, YOU ARE CLEARED TO LAND RUNWAY 1-1, WIND 1-6-0 DEGREES, 2-5 KILOMETERS OVER HOUR." At 15:33:20, DLH 2904 passed MM at 278 feet with CAS = 147 kts and GS = 168 kts and continued approach with landing configuration (landing gear down, full flaps [35°], manual control of thrust and of aircraft flight control surfaces) until touchdown.

During DLH 2904 approach to RWY 11 (magnetic course 113°), an atmospheric front passed from west to east over the Okęcie area, preceding the approaching aircraft. On final approach (in the area of MM), DFDR and QAR recorded a temporary (duration about 15 seconds) decrease of CAS = 154 kts by 12 kts. The aircraft passed the altitude of 50 feet with CAS = 158.8 kts, i.e. about 20 kts greater than V_LS recommended according to its weight. GS was 172.0 kts. The aircraft made its first contact with RWY 11 by its right landing gear assembly at the distance of 770 metres from RWY 11 threshold.

As it was recorded, the left landing gear touched the runway 9 seconds later, at a distance of 1525 metres from RWY 11 threshold, by CAS of 136 kts and GS of 154 kts. Already after first

contact of the right landing gear assembly with the runway, the pilot attempted to use wheel brakes, and while they failed to work, demanded the right-seat pilot to assist.

Only at the recorded moment, when the left landing gear touched the runway, automatic systems of the aircraft Airbus A320 depending on oleo strut (shock absorber) compression unlocked the use of ground spoilers and engine thrust reversers. The systems began to operate, the spoilers deployed to full angle (50°), thrust reverser system began to work and N1 of the engines came to 71%, but the wheel brakes, depending on wheel rotation being equivalent to circumferential speed of 72 kts began to operate after about 4 seconds.

Rollout of the aircraft progressed in conditions of heavy rain and with a layer of water on the runway. Aircraft was decelerated according to possibilities in actual conditions, but on the distance of last 180 metres of runway deceleration decreased by about 30 %. Residual length of the runway (left from the moment when braking systems had begun to work) was to small to enable the aircraft to stop on the runway. Seeing the approaching end of runway, and the obstacle behind it, the pilot managed only to deviate the aircraft to the right. The aircraft rolled over the end of runway with the speed GS = 72 kts and having passed next 90 metres collided by its left wing with the embankment, slipped over it destroying LLZ aerial located on the embankment, and stopped right behind the embankment. In effect of this movement the landing gear of the aircraft and the left engine were also destroyed. Evacuation of passengers, organised by 4 persons cabin crew in conditions of commencing aircraft flight, contributed to the rescue of 63 passengers of 64 on board. As far as the 2-person cockpit crew is concerned, the left-seat pilot

survived (injured), the other one, seated in the right seat, was killed. Aerodrome fire service extinguished the fire of the aircraft.

1.2 Injuries to persons

	Crew	Passengers
Fatal	1	1
Serious	2	49
Minor	1	4
None	2	10
Total	6	64

After the first-aid action decision was taken not to hospitalize eight persons, the remaining 54 were disposed to eight hospitals in Warsaw. None of their lives were in danger. 36 teams of ambulance service participated in the activities at the location.

1.3 Damage to aircraft

Fuselage

Upper part of the fuselage from the cockpit to the fin and to the bottom of the passenger cabin were burnt out, including cabin furniture and equipment. Front and aft passenger doors open with escape slides were deployed. Bottom part of the fuselage up to the wing area significantly deformed, the wing area broken. Radar dome and radar antenna detached from the aeroplane and destroyed. Aft part of the fuselage, from aft doors had minor deformation. The cockpit was burnt out. The stand-by airspeed indicator was the only readable instrument with a readout of 110 kts. Visible remnants of power levers were in the full forward position. Thrust reverser levers in OFF position. Fuel valve controls in OFF position. Flaps control lever in position for full deployment.

Wings

Entire left wing was seriously damaged, bottom part and the area in the vicinity of the fuselage was burnt. The left engine detached from the wing. Entire right wing had deformation in some regions, slots deployed, landing flaps FULL (angle 35°), spoilers 1 and 4 partially deployed.

Landing gear

Left main leg detached, wheel assembly partially burnt, no pressure in tyres. Right main gear complete, partially detached from the fuselage fittings. Wheels with tyres not damaged. Traces of local melting visible on the tyres. Front landing gear detached from the fuselage, wheels with tyres not damaged. Gears were taken for examination.

Flight controls

Control surfaces had local minor damages and deformation. Stabilizer in zero (neutral) position.

Engines

Left engine detached from the wing and moved about 5 metres forward from the wing, completely destroyed. Rotating elements destroyed in a way indicating that at the moment of impact the engine was in full operation. Visible parts of the control system are the evidence that at the moment of impact, the thrust reversers were ON (shafts of actuators of deflectors extracted for about 300 millimetres). Right engine did not have visible external damage nor did the attachment to the wing. Fan rotor blades deformed and locked inside the internal engine cowl. Visible damage of internal part of engine cowl caused by rotating fan rotor. This is the evidence

that the engine was running at the moment of impact. Thrust reverser deflectors nearly completely closed (remaining slot about 5 to 10 centimetres). According to DFDR records, the thrust reversers on both engines were ON until the moment of impact. Deflectors could close at the moment of impact. Engine Control Unit (ECU) was removed from the engine for examination.

Engine Control Unit

ECU as well as some other electronic units were removed from the aircraft for examination.

1.4 Other damage

Colliding with the embankment the aircraft destroyed the LLZ antenna mounted on the embankment. There were some other damages to the aerodrome fence and embankment surface, caused by the impact and by rescue activities.

1.5 Personnel information

1.5.1 Pilot in the left seat (under test) PF, male, aged 47 years, A320 captain

Licence:	Airline Transport Pilot Licence, valid until 28 February 1994, without limitations.
Instrument Rating:	Valid until 28 February 1994
Flying Experience:	Total all Types: 12,778 hours Total on accident type: 1,440 hours Preceding 90 days: None Preceding 24 hours: 5.01 hours Other types: B727, B707

1.5.2 Pilot in the right seat (testing) PNF, male, aged 47 years, A320 captain, instructor.

Licence:	Airline Transport Pilot Licence, valid until 20 January 1994, without limitations.
Instrument Rating:	Valid until 20 July 1994
Flying Experience:	Total all Types: 11,361 hours Total on accident type: 1,595 hours Preceding 90 days: 59.25 hours Preceding 30 days 7.67 hours Preceding 24 hours: 5.01 hours Other types: B727, B707

Accident flight was the last stage of test for the pilot being tested after his 90 days of not flying.

1.5.3 Passenger Cabin Crew

Four persons, including two women, fully qualified and with valid ratings.

They undertook the work on board of D-AIPN on 14 September after their required rest period.

1.6 Aircraft Information

1.6.1 Leading Particulars

Type:	A320-211
Serial Number:	105
Year of manufacture:	1990
Owner:	Deutsche Lufthansa Aktiengesellschaft von-Gablenz-Strasse 2-6 5000 Köln 21 Bundesrepublik Deutschland
Operator:	Deutsche Lufthansa Aktiengesellschaft von-Gablenz-Strasse 2-6 5000 Köln 21 Bundesrepublik Deutschland
Maximum Weight:	73,500 kgs
Total airframe hours:	7,546

Total cycles:	6,721
Powerplant:	Engine manufacturer CFM
Engine type:	CFM-56-5A1

	Serial No.	Total hours	Total cycles
Left engine:	731483	4,443	4,458
Right engine:	731285	6,297	5,392

1.6.2 Certification and formal status of the aircraft

State of registration and markings:	Germany, D-AIPN
Certificate of registration:	Issued 25 April 1990, validity unlimited
Certificate of airworthiness:	Issued 25 April 1990, validity unlimited
Certificate of maintenance:	Issued 1 July 1993
Radio Licence:	Issued 1 July 1993, validity unlimited
Noise certificate:	Issued 5 April 1990, validity unlimited

1.6.3 Structure and operation of braking system

Braking system consists of

Ground spoilers.

If selected "ON", the ground spoilers will extend if the following "on ground" conditions are met: either oleo struts (shock absorbers) are compressed at both main landing gears (the minimum load to compress one shock absorber being 6300 kg), or wheel speed is above 72 kts at both main landing gears.

Engine reversers.

If selected "ON", the engine reversers will deploy if the following "on ground" condition is met: shock absorbers are compressed at both main landing gears.

Wheel brakes.

The above mentioned conditions (wheel speed above 72 kts and both shock absorbers compressed) are not used to activate the brakes. With the primary mode of the braking system, the brakes may be used as soon as wheel speed at both landing gears is above 0.8 V_0 where V_0 is a reference speed computed by BCSU. With the alternate mode of the braking system, the brakes may be used as soon as the A/SKID-NOSE WHEEL STEERING switch has been selected to the OFF position by the crew.

1.6.4 Automatic equipment

Automatic operation of aircraft braking systems was described in 1.6.3 above.

1.6.5 Other relevant aircraft systems

The aircraft is fitted with two independent EFIS (Electronic Flight Instrument system). The system provides wind display - direction and velocity value, and displays speeds: GS and TAS.

1.7 Meteorological information

Weather conditions during Lufthansa flight LH 2904/14 on the leg Frankfurt - Warsaw on 14 September 1993.

Synoptic situation

There was low over Poland. At 12:00, the centre of the low with the pressure 985 hPa was over Belgium. There was a system of atmospheric fronts connected with the low. Warsaw was in the warm part of low, i.e. after warm front passing and before passing of the cold one. The cold front passed at 12:00 over Kolo and moved eastward to Warsaw. Meteorological situation is displayed on the synoptic chart valid for 12:00. At 14:00, the cold front passed Lodz and its position was the line Plock - Sulejow see synoptic chart actual for 14:00. At 15:00, the cold front was several tens of kilometres west of Warsaw and continued to move eastward - see synoptic chart for 15:00. There were some showers and sporadic storms on the front line and after it passed. On the isobaric surface 850 hPa, Poland was on the border of the low. Wind in Warsaw was 190°, 15 m/s, temperature +10°C - see 850 hPa chart of 12:00.

Forecasts TAF for aerodrome Okęcie

Forecasts TAF were prepared in fixed times and were passed over for international exchange. Three consecutive forecasts with validity periods: 09:00 - 18:00, 12:00 21:00 and 15:00 - 24:00 are presented in Appendix. The forecast for the period 09:00 - 18:00 predicted some showers at 14:00 to 18:00 with possible thunderstorms, clouds Cb and wind gusts up to 13 m/s. In the forecast for 12:00 - 21:00, showers with possible storms and Cb clouds were predicted at 15:00 to 18:00. In the forecast for 15:00 - 24:00, showers with possible storms and Cb clouds were predicted at 15:00 to 21:00. This last TAF was received by Lufthansa crew prior to departure for Warsaw.

METAR messages for Warsaw

METAR messages were prepared every 30 minutes and were passed over for international exchange. Messages for the period 13:00 to 18:00 are presented in Appendix. Cold front passed in the time between the METARs of 15:00 and 16:30. At 15:30, wind still was 150°/6 m/s, but Cb clouds began to create. At 16:00, the wind already was 270°/10 m/s, there were Cb clouds and low clouds STC on 240 metres beneath; showers just stopped.

Meteorological information passed over to traffic control center and to ATIS.

Meteorological office on the aerodrome Okęcie transmitted the changes of meteorological conditions to the monitors located on the stations of air traffic controllers and for recording on ATIS. Documentation of these changes and of the transmissions in the period 13:22; 16:00 is contained in the register of transmissions. Cb were announced first at 14:59 and information repeated at 15:22, 15:28, 15:32, 15:35 hours.

A shower was announced at 15:28, and heavy shower at 15:35. Wind was given as follows:

at 15:22 - 150° 22 km/h

at 15:28 - 160° 25 km/h

at 15:32 - 170° 32 km/h

at 15:37 - 210° 36 km/h

The pressure was given as follows:

at 14:58 - QNH 997 hPa, QFE 984 hPa, 738 mm Hg

at 15:35 - QNH 999 hPa, QFE 986 hPa, 739 mm Hg

The temperature was given as follows:

at 14:58 - t 22°C, t_d 17°C

at 15:41 - t 17°C, t_d 16°C

Meteorological information from other sources.

Windshear in the area of aerodrome Warsaw - Okęcie was reported to air traffic services by some earlier landing aircraft.

Meteo information received by the Lufthansa crew prior to departure.

The crew received in Frankfurt the following TAF for Warsaw - Okęcie prior to departure from Frankfurt aerodrome:

1524 17005MPS 9999 BKN030 TEMPO 1521 6000 SHRA BKN020CB

PROB30 TS BECMG 2124 4000 RA 0VCO15=

as well as two consecutive METARs from Frankfurt:

1250 EDDF 190017KT 9999 SCT040 BKN080 19/10 QO996 NOSIG

1257 EDDF 19016G26TKS 9999 SCT040 BKN080 18/10 QO996 NOSIG

It was not found whether the crew of the flight LH 2904/14 was supplied with the full set of synoptic charts and especially SWC charts (significant weather changes) that would caution them against the cold front in the Warsaw area.

1.8 Aids to navigation

During the flight from Frankfurt, after entering FIR Poland, the aircraft used all active on route aids related to assigned route and without any interference captured the approach course of ILS for RWY 11 of Okęcie aerodrome. Aids to navigation were not significant in this accident.

1.9 Communications

The crew kept undisturbed radio communication with Polish air traffic control services ATC, APP and TWR until landing. The last contact with TWR was at 15:32:12.

1.10 Aerodrome and ground aids

Status of aerodrome Warsaw Okęcie was in accordance with AIP - Poland. Runway in use for landing was RWY 11 of 2800 m length. Runway RWY 15 of 3690 m length was assigned for departures.

1.11 Flight recorders

The following flight recording equipment in normal condition was removed from the aircraft/.

1.11.1 Flight data recorders

1. DFDR model UFDR Sundstrand Data Control Inc. Digital Flight Data Recorder Mfg. Part No. 980-4100-AXUN, Serial No. 90/72, DATE 90 38.
2. QAR - Schlumberger model PC 6033/3-55|614 Quick Access Recorder
3. CFDIU - SEXTANT AVIONIQUE Centralized Fault Display Interface Unit, P/N B401 ACM 0404, S/N 164.

4. BSCU - Messier-Bugatti Brake System Control Unit, P/N C202 1622 C2427 S/N 456.

DFDR was opened by the commission on 22 September 1993 at CENTRE d'ESSAIS EN VOL in BRETIGNY, France. Contents of it's tape and of tape of QAR was subsequently transferred to digital printouts and floppy discs. Excerpts of digital data are presented in appendices to this Report.

1.11.2 Records of radio correspondence and of sounds in cockpit

1. Cockpit Voice Recorder model A100A, made by FAIRCHILD AVIATION RECORDERS, SARASOTA, FLORIDA.

P/N 93-A100-82, S/N 54634, Date 4-89

CVR was opened by the commission and replayed on 21 September in BEA laboratory in Paris (rue Lecourbe 246) in the presence of representatives of GKBWL Warsaw, BEA Paris and FUS Braunschweig. Readout of the contents was made by FUS - Flugunfalluntersuchungsstelle in Braunschweig, Bundesrepublik Deutschland and transcripts are appendices to this Report.

Radio correspondence was also recorded on recorders of air traffic control services. Readouts of both groups of recording devices were subsequently used for analyses and conclusions.

1.12 Wreckage and place information

1.12.1 Place information

Place of the accident was the embankment located 90 metres behind the end of RWY 11 and 60 metres from the concrete surface (see Appendix 2.4 Plan of RWY11 end). The aircraft rolled out behind the end of runway, hit the embankment mentioned earlier, destroying the LLZ aerial

mounted on the embankment, and came to a stop on the other side of the embankment. In effect of this movement, the landing gear of the aircraft and the left engine were also destroyed. Traces found on the runway surface at the end of it and on the ground along the way of aircraft allow to state that at the moment of collision with the embankment the aircraft was inclined by about 45° to the right and at the final stage the declination increased, but the direction of movement was not changed. Traces on the asphalt part of the runway are dark coloured, indicating braking and steering action, but on the part covered with concrete - light, denoting the cleaning action of water compressed to high pressure under the tyres.

1.12.2 Wreckage information

Wreckage has been described in Section 1.3 Damage to aircraft.

After the fire had been extinguished about 6000 litres of fuel was drained from the tanks of wreckage.

1.13 Medical and anatomopathological information

Autopsy of the body of the pilot in command (PNF), who was seated in the right seat instructing the left seat pilot (PF), indicates that he was killed at the impact due to collision with cockpit interior elements. It was confirmed by extensive damage to the internal organs, namely: rupture of pericardial sac and of the main artery wall, rupture of internal membrane of aorta, perforation of the lungs with broken ribs. Presence of the carbon dioxide haemoglobin or alcohol in the blood of the pilot was not stated. During examination of stomach contents and kidney neither drugs nor medicines affecting the capacity or capability to perform pilot duties were discovered.

In the blood of the not survived passenger 22.6% of carbon dioxide haemoglobin was found, and in the opinion of those who performed the autopsy intoxication with carbon dioxide in the environment of the high temperature was the cause of the death.

Injury profile was as follows:

Spine injuries	21
Head injuries	8
Chest injuries (broken ribs)	8
Abdomen contusions	4
Broken limbs	5
Burns	1
Other	9
Total	56

1.14 Fire

In the collision of the aircraft with the embankment and with LLZ aerial located on it the fuel tanks of the aircraft were broken and the fuel began to spill on the left side of fuselage. It was ignited, most probably because of contact with hot parts of the damaged left engine or with the electrical system of the aerial. It caused the fire of the left wing. The fire spread to an area of about 600 square metres. Shortly the fire penetrated into the passenger cabin, creating the smoke at first, and later filling the whole cabin. When, in three minutes from the emergency call, five Aerodrome Fire Service cars came to the spot, they managed to extinguish the external fire and the passengers remaining in the area of danger and blocking access for fire service, were successfully evacuated for the safe distance.

It was impossible to stop the fire inside the aircraft. Neither the foam introduced through the open entrance, nor the attempts to open the emergency exits on the left wing and to break into the cabin could help, at last pouring the foam through the broken out cockpit windows gave the positive result. After two minutes from the beginning of the activities on the spot the tank in the middle part of the wing blew out. Next 30 minutes the extinguishing of the burning fuselage through the hole created in the roof was continued.

15 minutes after the emergency call four cars of the national fire service came to the aircraft and entered into action. Because of the actual situation next fire service units coming to the place were turned back.

Calculation of the residual fuel, remaining on board at the moment of impact, and the amount drained from the wreckage indicates that about 2900 litres of aviation kerosine JA-1 was burnt in the fire and due to action of the high temperature of oxygen bottles about 12000 litres of oxygen was released, what obviously increased the intensity of the fire.

1.15 Survival aspects

From a midst of four persons of the cabin crew (during the landing they were seated in two pairs, one near to the front entrance and the other near to aft entrance) two only were capable to act immediately. A stewardess from the aft team, due to breathing difficulties, fainted after opening the door and initialization of the escape slide and was unable to take part in the further activities, and chief steward (with injured head), who was in the front part of cabin, remained unconscious all the time of passenger evacuation. After regaining consciousness he managed to release the

injured pilot blocked in the cockpit, enabling him to leave the aircraft through the open front door. But he was not able to lift the body of the commander remaining in the cockpit.
It is to be stated that the prompt and successful evacuation of 63 persons out of the passenger cabin by increasing smokiness and intensive fire invasion could be achieved thanks to the behavior of these persons in spite of the injuries and their lack of full physical proficiency and was carried out by their own with mutual help. Of course those two cabin attendants played a significant and unquestionable role preventing the panic and organizing the movement of passengers to the exits.

The passenger seated in the utmost left place in "business" class sustained the fracture of the first lumbar vertebra and of both hands what made him most probably unable to leave the seat by his own, but the temporary loss of consciousness in effect of the impact did not allow him to draw the attention of other passengers and cabin attendants to himself. It is not unlikely that the promptly growing smoke in the cabin caused him to lose consciousness or led to its degradation to the same effect.

Situation would be significantly more severe if the injured persons needed individual direct assistance by leaving the wreckage or if the character of injuries required immediate intervention, e.g. because of hemorrhage or need for reanimation. The sufficient amount of ambulances did not come to the place quickly enough and some injured were carried to the airport by casual means of transport (e.g. tarmac bus).

1.16 Tests and research

In the course of work of the Commission series of analyses and research was carried out.
It included interpretation of the contents of memories of all recorders mentioned in 1.11 and examination of the status of brake assemblies, or the types of the landing gears and of engine thrust reverser systems as well as of traces of the tyres on the runway.

1.17 Aquaplaning

Aquaplaning that affected Lufthansa D-AIPN during rollout arose in various stages of the rollout, probably from the beginning.
It could be caused at the same time by:

- uneven layer of water up to several millimetres covering the surface of the runway,
- high touchdown speed,
- considerable wear of three of four tyres of main landing gear.

On the basis of analysis of both traces on the runway surface and the character of damage to the tyres it had to be assumed that at the final part of the runway covered with the concrete, aquaplaning was in the fully developed form as sliding of blocked wheels on the water steam cushion. It caused the radical decrease of the coefficient of friction, which was confirmed by a record of braking progress as found in the flight data recorder.

This subject was worked up by the company "Consulting Lotniczy AVIAPOL", Poznan.

2. Analyses

2.1 Meteorological conditions

Landing of the Lufthansa aircraft at 15:33 15:34 was carried out while the cold front was passing over the aerodrome area, on the head of Cb cloud with heavy shower. The shower began at 15:28, initially as light, but the heavy one occurred in the period 15:33 to 15:41, i.e. during merely eight minutes, and at 15:53 it stopped completely. Amount of precipitation measured at the weather station was 2 mm. Taking into account the character of the shower and the accompanying strong wind, that could decrease the amount measured, it could be taken that the real precipitation on RWY 11 could amount to 3-4 mm.

Wind record is enclosed. On this record the wind readout is delayed for about 3 minutes in comparison to the real time - a statement is enclosed. However, the wind readout without the declared time correction comes closer to the values obtained from DFDR. The record indicates that the change of wind direction from 160° to 270° progressed continuously in the period of 18 minutes, and the maximum wind velocity occurred after the landing at 15:40 and came in gusts to 16 m/s. According to the meteo office interpretation of the record the wind at the time of landing was 220° by 10 m/s, and in gusts the velocity was coming to 15 m/s, and it could be variable with the tendency to come nearer to west.

The values taken from DFDR differ from those given above and are as follows:

- the tailwind component at the moment of aircraft passing over OM at the radio altitude of about 2100 ft was 25 kts,
- at the beginning of touchdown was 18 kts and gradually decreased.

The cloud base at the time of landing was about 250 m and visibility from meteo office was 4 kilometres. Taking into account that the precipitation on RWY 11 could be more intensive, it may be assumed that in the place of landing the visibility could be decreased to about 3000 - 2500 metres.

2.2 Sequence of in flight events

2.2.1 Weight and balance

According to Loadsheet:

Zero Fuel Weight of the Aircraft	51,431 kGs
Take Off Fuel	10,300 kGs
Take Off Weight	61,731 kGs
Landing Weight (estimation)	58,380 kGs

As calculated after the flight, based on the actual flight time:

Fuel consumed	2,947 kGs
Residual fuel (in aircraft tanks)	7,353 kGs
Landing Weight (actual)	58,884 kGs

2.2.2 Flight prior to initial approach

The aircraft took off from Frankfurt at 14:47 for the flight DLH 2904. Take-off weight was 61731 kGs. Estimated flight time was 01:18. The cruise over the territory of Poland was performed at FL330. On the final stage at this level CAS was 268 kts and ground speed GS = 551 kts. Because of the significant tailwind component, flight time was reduced in comparison to

the estimation. In the period 15:08:07 to 15:11:58 the crew listened to ATIS Warsaw and received several times the following information UNIFORM:

"GOOD AFTERNOON, THIS IS WARSAWA, INFORMATION UNIFORM, EXPECT RADAR VECTOR FOR I-L-S RUNWAY 1-1, ARRIVAL RUNWAY 1-1, DEPARTURE RUNWAY 1-5, TRANSITION LEVEL 5-0, INFORMATION TAXIWAYS OSCAR 2, PARTLY MIKE 2 CLOSED, WIND 1-5-0 DEGREES, 2-2 KILOMETERS PER HOUR, VISIBILITY 1-0 KILOMETERS, CLOUDS 2 OCTAS C-B 2000 METERS, 4 OCTAS 2000 METERS, TEMPERATURE 2-2, DEW POINT 1-7, Q-N-H 9-9-7 HECTOPASCAL Q-F-E 9-8-4 HECTOPASCAL, 7-3-8 MILLIMETERS, NOSIG"

At 15:14:29, the crew asked ATC Warsaw to be cleared for initial approach and at 15:14:33 was cleared to descend to FL190. At 15:19:12, Warsaw told the crew to continue the flight directly to VOR WAR. At 15:21:09, the crew reported FL190 and was told to keep this level. At 15:22:50, Warsaw told DLH 2904 to change over for contact with Approach Centre on 128.8 MHz. During this phase of flight, no event occurred of any significance for the course of the accident.

2.2.3 Approach

At 15:22:59 the crew of DLH 2904 at FL190 established contact with Approach Control and was told to descend to FL50 towards the VOR WAR and cleared to keep high approach speed. The crew continued approach with the speed CAS = 250 kts and GS = 380 kts. At 15:25:24, Approach Control instructed the crew to continue descent to 950 m on QFE. At 15:27:46, Approach Control told the crew to commence speed reduction to the value of the approach speed

appropriate for this aircraft. At this moment the aircraft was passing the altitude of about 3300 feet and the crew began to reduce the speed gradually. According to AOM 11.70/1 for the estimated landing weight 58 tons and FULL configuration the speed V_LS = 130 kts. At 15:28:16 Approach Control radioed the following information:

"JET AVIATION 1-0-1, THE PRECEDING TRAFFIC HAS REPORTED WINDSHEAR ON FINAL APPROACH 1-1", which had to be heard by DLH 2904.

At 15:32:18, the crew of DLH 2904, descending through the altitude about 1400 feet decreased the speed to CAS = 150 kts, i.e. to the speed about 20 kts greater than V_LS and endeavoured to keep this speed. At 15:29:10 Approach Control called:

"LUFTHANSA 2-9-0-4, TURN RIGHT 0-8-0 TO LOCK ON I-L-S 1-1, CLEARED APPROACH AS NUMBER 2, CALL WHEN ESTABLISHED, 2-4 KILOMETERS TO GO"

At 15:30:46, DLH 2904 reported establishing and was instructed to continue approach as Number 1 and to switch over to the Tower frequency 126.6 MHz. At 15:31:00, DLH 2904 established contact with TWR on their frequency. At 15:31:07, Tower called:

"LUFTHANSA 2-9-0-4, CONTINUE I-L-S APPROACH, CALL ME OUTER MARKER, WIND 1-6-0 DEGREES, 2-5 KILOMETERS PER HOUR AND BEFORE YOUR LANDING IT WAS REPORTED WINDSHEAR ON THE FINAL RUNWAY 1-1"

DLH 2904 replied "ROGER, THAT'S UNDERSTOOD. I CALL YOU OUTER MARKER"

The aircraft passed the altitude about 2800 feet at that time and it's airspeed recorded as Computed Airspeed was CAS = 163 kts and ground speed GS = 180 kts. At 15:31:26, just landed JETAVIATION 101 called:

"WARSAW TOWER, GOOD EVENING, JETAVIATION 1-0-1 IS VACATING RUNWAY 1-1 ON TAXIWAY E-O, FOR INFORMATION WE HAD SEVERE WINDSHEAR ON FINAL"

At 15:32:12 the Tower called:

"LUFTHANSA 2-9-0-4, YOU ARE CLEARED TO LAND RUNWAY 1-1, WIND 1-6-0 DEGREES, 2-5 KILOMETERS PER HOUR"

At 15:33:20, DLH 2904 passed over MM on the altitude of 278 feet with CAS = 147 kts and GS = 168 kts and continued to approach in landing configuration (undercarriage down, flaps FULL = 35°), with manual operation of flight controls and thrust. During the final approach (about MM) momentary decrease of airspeed from the value CAS = 154 kts by 12 kts was recorded on DFDR and QAR with duration of about 15 seconds. The aircraft descended through the altitude 50 feet with CAS = 158.8 kts, i.e. about 30 kts greater than V_LS recommended by actual weight of the airplane and with the ground speed GS = 172.0 kts.

Time	RADHEI	AIRSPD	GNDSPD	GRDSPD	DIST from MM	DIST from THR	Event
(UTC)	[ft]	[kts]	[kts]	[m/s]	[m]	[m]	
15:33:27	278	147.0	168.0	86.43	0.0	-1080.0	MM flyover
15:33:28	268	148.8	170.0	87.46	86.4	-993.6	
15:33:29	240	144.8	170.0	87.46	173.9	-906.1	
15:33:30	220	142.0	170.0	87.46	261.3	-818.7	
15:33:31	202	144.0	170.0	87.46	348.8	-731.2	
15:33:32	186	145.8	172.0	88.48	436.3	-643.7	
15:33:33	176	142.5	172.0	88.48	524.7	-555.3	
15:33:34	160	145.5	172.0	88.48	613.2	-466.8	
15:33:35	144	152.0	172.0	88.48	701.7	-378.3	
15:33:36	136	164.5	172.0	88.48	790.2	-289.8	
15:33:37	124	157.0	172.0	88.48	878.7	-201.3	
15:33:38	100	154.8	172.0	88.48	967.1	-112.9	
15:33:39	80	149.2	172.0	88.48	1055.6	-24.4	THR-11 flyover
15:33:40	66	158.8	172.0	88.48	1144.1	64.1	
15:33:41	54	159.2	172.0	88.48	1232.6	152.6	RA = 50 ft
15:33:42	42	158.0	172.0	88.48	1321.1	241.1	
15:33:43	30	155.2	172.0	88.48	1409.5	329.5	
15:33:44	20	153.0	172.0	88.48	1498.0	418.0	
15:33:45	10	152.5	172.0	88.48	1586.5	506.5	
15:33:46	6	157.8	170.0	87.46	1675.0	595.0	Throttles on
15:33:47	2	153.5	170.0	87.46	1762.5	682.5	idle
15:33:48	0	151.5	170.0	87.46	1849.9	769.9	RLG on ground
15:33:49	0	152.0	166.0	85.40	1937.4	857.4	
15:33:50	0	149.8	166.0	85.40	2022.8	942.8	
15:33:51	0	149.2	164.0	84.37	2108.2	1028.2	NLG on ground
15:33:52	0	147.2	164.0	84.37	2192.5	1112.5	Reverser
15:33:53	2	143.5	162.0	83.34	2276.9	1196.9	levers FULL
15:33:54	0	143.0	160.0	82.31	2360.3	1280.3	
15:33:55	0	142.8	158.0	81.28	2442.6	1362.6	
15:33:56	0	142.2	158.0	81.28	2523.8	1443.8	
15:33:57	0	136.0	154.0	79.22	2605.1	1525.1	LLG on ground
15:33:58	0	133.5	152.0	75.20	2684.3	1604.3	
15:33:59	0	133.8	148.0	76.14	2759.5	1679.5	Spoilers fully deployed (50°)
15:34:00	0	124.8	144.0	74.08	2835.7	1755.7	j_xmax=-0.28
15:34:01	0	118.0	136.0	69.96	2909.8	1829.8	Reversers start to move
15:34:02	0	118.2	132.0	67.91	2979.7	1899.7	Full reversers achieved (71%)
15:34:03	0	108.0	130.0	66.88	3047.6	1967.6	
15:34:04	0	110.2	126.0	64.82	3114.5	2034.5	
15:34:05	0	104.0	118.0	60.70	3179.3	2099.3	
15:34:06	0	99.0	114.0	58.65	3240.0	2160.0	

15:34:07	0	95.5	112.0	57.62	3298.7	2218.7	
15:34:08	0	92.8	108.0	55.56	3356.3	2276.3	
15:34:09	0	89.5	102.0	52.47	3411.9	2331.9	
15:34:10	0	86.8	100.0	51.44	3464.3	2384.3	
15:34:11	-2	85.2	96.0	49.39	3515.8	2435.8	
15:34:12	0	81.0	94.0	48.36	3565.2	2485.2	
15:34:13	0	79.2	88.0	45.27	3613.5	2533.5	
15:34:14	0	78.0	84.0	43.21	3658.8	2578.8	
15:34:15	-2	75.2	82.0	42.18	3702.0	2622.0	j_x decrease from -0.22
15:34:16	-2	61.5	80.0	41.16	3744.2	2664.2	to -0.16
15:34:17	0	69.0	76.0	39.10	3785.3	2705.3	
15:34:18	0	69.2	74.0	38.07	3824.4	2744.4	Full rudder right
15:34:19	0	67.8	72.0	37.04	3862.5	2782.5	End of runway
15:34:20	-2	63.8	70.0	36.01	3899.5	2819.5	
15:34:21	-2	67.2	58.0	29.84	3935.6	2855.6	
15:34:22	0	0.0	0.0	0.0	3965.4	2885.4	Impact

First three characteristic points may be considered as elements of the final approach phase.

Point			A	B	C
Time UTC	UTC		15:33:27	15:33:39.3	15:33:41.3
Time DFDR	TDFDR		1703		
Distance from THR-11	THRDST	[m]	-1080	0	181.8
Radio Altitude	RADHEI	[ft]	278	72	50
ILS-GP Altitude	HILSGP	[ft]	262	64	31
Indicated Airspeed	AIRSPD	[kts]	147.0	149.2	158.8
Ground Speed	GRDSPD	[kts]	168.0	172.0	172.0
Engine RPM	N1	[%]	60.0	58.5	56.1
Joystick Position	GAUCHI	[deg]	R0.18	R0.35	R1.99
Roll	ROLL	[deg]	R1.01	R0.92	L0.70
Longitudinal Acceler.	LNACC	[-]	+0.15	-0.020	-0.020
Rudder Pedals Position	DIR	[deg]	R0.62	L1.23	L0.63
Aircraft Heading	HEADNG	[deg]	118	116	114

True enough it might be questioned what moment could be considered as the boundary between approach and flare-out phases, it should be noted however, that some events of essential significance for further progress of the flight occurred at the approach phase, as follows:

a) DLH 2904 crew three times heard the warning of windshear in RWY 11 approach area.

b) The crew complied with only one of the recommendations given in A320 OAM, Section "Supplementary Procedures - Adverse Weather", page 5.24/18, namely: they increased the speed by 20 kts.

c) The crew switched off the weather radar; the radar could help to evaluate the situation properly.

d) The crew did not take into account the wind display on EFIS and did not consider the discrepancy between these data and the information on the wind given by air traffic services. They did not take into account that the tailwind component displayed on EFIS exceeds the value defined by OAM as acceptable for this aircraft.

e) The crew did not analyse whether by the increased approach speed RWY 11 would provide enough distance to enable them to suppress the increased kinetic energy of the aircraft.

f) The crew used FULL flaps configuration, which on this aircraft disabled the braking system until recorded touchdown.

2.2.4 Flare out

This phase falls within the period 15:33:39.3 to 15:33:48 (DFDR time 1722 to 1724) and contains the segment from the pass over RWY 11 threshold to the first recorded contact of the aircraft (right landing gear assembly) with RWY 11 surface. It is to be noted, that especially in the case of this phase, its boundaries are conventionally assumed.

Point			D	E	F
Time UTC	UTC		15:33:43.2	15:33:46	15:33:48
Time DFDR	TDFDR			1722	1724
Distance from THR-11	THRDST	[m]	350	595.0	769.9
Radio Altitude	RADHEI	[ft]	18	6	0
ILS-GP Altitude	HILSGP	[ft]	0	0	0
Indicated Airspeed	AIRSPD	[kts]	154.7	157.8	151.5
Ground Speed	GRDSPD	[kts]	172.0	170.0	170.0
Engine RPM	N1	[%]	52.3	49.9	44.9
Joystick Position	GAUCHI	[deg]	L7.94	R4.04	R8.61
Roll	ROLL	[deg]	R2.46	R2.37	R3.21
Longitudinal Acceler.	LNACC	[-]		-0.039	-0.039
Rudder Pedals Position	DIR	[deg]	L0.65	L8.18	L11.42
Aircraft Heading	HEADNG	[deg]		111	114

It is to be noted, that the pilot kept - because of the windshear - not only increased speed, but also increased thrust down to relatively very low altitude, and consequently the aircraft - after passing over the threshold - occurred to be distinctly above the ILS glide path. Throttles were moved back to "idle" at the point E at an altitude of 6 feet. This caused significant extension of the flare-out phase. Point F is only apparent end of this phase, caused by casual (in the counteraction against crosswind) contact of the aircraft with the ground in considerable right bank (3.21°); this contact was strong enough to compress this one oleo strut as much as was

needed for oleo switch to come on. If the aircraft approached the ground without this bank, the oleo switch would come on at a considerably greater distance. It is of importance that this first, in a way forced contact with the ground occurred at the distance as far as 770 m from RWY 11 threshold and the bounce of the right landing gear brought to the crew the false impression that both gears had contacted the runway. Further actions of the crew confirm this assumption. The crew did not draw the right conclusions from the course of the flare-out phase and did not appraise their own chances in the real situation - with that speed and that point of touchdown.

2.2.5 Touchdown

This phase falls within the period 15:33:48 to 15:33:57 UTC (DFDR time 1714 to 1733) and envelops the segment from the first recorded signal of contact of the right landing gear with the runway to the moment of recorded the last leg (in this particular case of the left main landing gear) being in full contact with the runway.

Point		F	G	H	I
Time UTC		15:33:48	15:33:51	15:33:52	15:33:57
Time DFDR		1724	1727	1728	1733
Distance from THR-11	[m]	769.9	1028.2	1112.5	1525.1
Radio Altitude	[ft]	0	0	0	0
Indicated Airspeed	[kts]	151.5	149.2	147.2	136.0
Ground Speed	[kts]	170.0	164.0	164.0	154.0
Engine RPM	[%]	44.9	32.0	30.0	29.6
Joystick Position	[deg]	R8.61	R13.18	R10.63	R11.6
Roll	[deg]	R3.21	R0.66	R0.92	L0.48
Longitudinal Acceler.	[-]	-0.039	-0.094	-0.1OO	-0.180
Rudder Pedals Position	[deg]	L11.42	L3.74	L0.15	L1.00
Aircraft Heading	[deg]	114	114	115	115

By the aircraft weight 58 tons the touchdown with the speed near to earlier calculated V_LS = 130 kts should be expected. In fact the first recorded casual - and in a way forced - contact with the ground occurred at the point F by CAS = 151.5 kts and GS = 170.0 kts. Full recorded touchdown occurred only at the point I with the speed CAS = 136.0 kts, because only by this speed such decrease of the residual lift was possible, that the weight of the aircraft could cause the oleo struts to compress sufficiently for oleo switches to close (provided nearly ideally symmetrical compression of both main landing gear legs is achieved). It was confirmed by the analysis 460.169 carried out by AEROSPATIALE AVIONS. Again at this phase of flight the crew did not appraise the situation properly and attempted to brake only instead of initiating go-around.

2.2.6 Rollout and stop

This phase falls within the period 15:33:57 to 15:34:22 UTC (DFDR time 1733 to 1758) and encompasses the segment from the recorded contact of the left main landing gear (the last one) with the runway surface to the full stop of the aircraft.

Point		I	J	K	L
Time UTC		15:33:57	15:33:59	15:34:00	15:34:02
Time DFDR		1733	1735	1736	1738
Distance from THR-11	[m]	1525.1	1679.5	1755.7	1899.7
Radio Altitude	[ft]	0	0	0	0
Indicated Airspeed	[kts]	136.0	133.8	124.8	118.2
Ground Speed	[kts]	154.0	148.0	144.0	132.0
Engine RPM	[%]	29.6	32.2	37.0	70.6
Joystick Position	[deg]	R11.60	R13.36	R15.03	R10.99
Roll	[deg]	L0.48	L0.04	L0.31	L0.44
Longitudinal Acceler.	[-]	-0.180	-0.267	-0.260	-0.251
Rudder Pedals Position	[deg]	L1.00	L6.98	L4.64	L6.48
Aircraft Heading	[deg]	115	115	115	116

Point		M	N	O	P
Time UTC		15:34:15	15:34:18	15:34:19	15:34:22
Time DFDR		1751	1754		
Distance from THR-11	[m]	2622.0	2744.4	2800.0	2890.0
Radio Altitude	[ft]	0	0	0	0
Indicated Airspeed	[kts]	75.2	69.2	67.8	67.2
Ground Speed	[kts]	82.0	74.0	72.0	58.0
Engine RPM	[%]	71.1	71.1	71.0	71.0
Joystick Position	[deg]	R8.35	R19.95	R19.95	R19.95
Roll	[deg]	R0.31	R0.09	L0.09	L1.19
Longitudinal Acceler.	[-]	-0.172	-0.133	-0.137	-0.267
Rudder Pedals Position	[deg]	L11.47	P21.15	P19.09	P2.10
Aircraft Heading	[deg]	121	130	145	158

The remaining runway length available at the moment of the recorded contact of both main landing gears with the runway surface was 1275 m.

Airbus A320 automatic systems dependent on compression of oleo struts armed all three braking systems only at the moment of recorded contact of the left main landing gear assembly with the

runway (15:33:57). Systems began to work, spoilers were deployed to FULL (50°), reverser systems went into operation and N1 of the engines come to 71%, but wheel brakes, dependent on the rotation gain to circumferential speed of 72 kts began to operate about 4 seconds later.

Rollout, as well as the whole landing and final approach progressed in the heavy rain and with the presence of the layer of water on the runway. Aquaplaning that occurred during the rollout phase considerably degraded the braking effectiveness. Deceleration of the aircraft was in accordance with its abilities in those circumstances, but on the last 180 metres decreased by about 30%. The runway length remaining at the moment of beginning of brake system action was insufficient to stop the aircraft on the runway.

Seeing the approaching end of runway and the obstacle behind it, the pilot struggled to deviate the aircraft to the right. Aircraft began to turn right, but its centre of gravity movement path did not bend. The aircraft rolled over the end of runway with the speed GS = 72 kts and after passing next 90 metres collided with the embankment, slipped over it damaging the LLZ aerial located on the top of the embankment, and stopped just behind the embankment. In effect of this movement the landing gear of the aircraft and the left engine were also destroyed.

2.2.7 Landing distance required

a) Airplane Operations Manual AOM A320A gives the following landing and rollout distances for the weight and configuration discussed and for the conditions existing at the time of landing

(QFE 984 hPa, t = 22°C, runway wet):

FAR based, read from 9.30.4, i.e. demonstrated value multiplied by 1.667	Actual, calculated from the value given in the first column	Actual, given in 11.70.2	Actual given in 8.20.6 for runway covered with 6 mm of water	
				Landing with no wind
				Total landing distance
1540 m [1]	924 m [2]	1227 m [1]	1637 m [1]	
				Rollout with no wind (from AOM 320A the airstage 305 m assumed)
1032 m [2]	619 m [2]	922 m [2]	1332 m [2]	
				Average value of deceleration during rollout
-0.221g (-2.17 m/s²)	-0.368g (-3.6 m/s²)	-0.247g (-2.43 m/s²)	-0.171g (-1.68 m/s²)	
				Speed at specific points (distance from THR 11)
L = 2800 m	0	0	0	
L = 2890 m	0	0	26.89 kts	
				Landing with tailwind - 10 kts
				Total landing distance
1740 m [1]	1044 m [2]	1447 m [1]	1964 m [1]	
				Rollout with the tailwind -10 kts (from AOM 320A the airstage 305 m assumed)
1232 m [2]	739 m [2]	1172 m [2]	1659 m [2]	
				Average value of deceleration during rollout
-0.215g (-2.105 m/s²)	-0.358g (-3.51 m/s²)	-0.225g (-2.213 m/s²)	-0.159g (-1.563 m/s²)	
				Speed at specific points (distance from THR 11)
L = 2800 m	0	0	67.3 kts	
L = 2890 m	0	0	59.0 kts	

[1] Values taken from Airplane Operations Manual AOM 320A.
[2] Values calculated from the data given in AOM 320A.
[3] Values read from flight data recorder.

b) For the ground speed recorded at the moment of full touchdown (on all three landing gears) as 145 kts, i.e. by 24 kts greater than the landing speed given in 11.70.1, the rollout distance calculated roughly on general formulas (in view of the tailwind limitation to 10 kts - AOM 320A does not contain data for greater velocities of wind) would amount to 1746 m² and average deceleration would be -0.183g (-1.80 m/s²). On the other hand the speed at the crossing of end of runway (L = 2800 m) would be 80.0 kts, and at the crossing of embankment base boundary line (L = 2890 m) would be 71.9 kts.

c) Actual deceleration values during rollout in Warsaw were:

- at the initial phase (15:34:00) -0.27g (about -2.6 m/s²)[3]

- at the final phase (15:34:16) -0.14g (about -1.4 m/s²)³

- average for the whole rollout -0.213g (about -2.1 m/s²)³

This value is greater than that resulting from the landing distance given by AOM 320A for landing on the runway covered with 6 mm of water (-0.180 to -0.195), it is to be noted that AOM gives the values for landing without thrust reverser use.

d) For the average value of deceleration actually achieved in progress of rollout the distance from the end of runway to imaginable full stop (i.e. the "missing" distance) would amount to about 310 m, and from the boundary line of embankment base - about 220 m.

For the deceleration value -0.13 g (-1.27 m/s²) achieved at the final phase of movement on the runway those distances would be about 440 m and 350 m respectively.

Assuming no deceleration ramp for (15:34:15) and linear deceleration decrease up to the end of runway to the value of -0.18 g, the average value for this segment would be -0.19 g (-1.866 m/s²). Then the ground speed, having at that moment the actual value of 82.0 kts would decrease to 65.0 kts at the moment of runway end crossing, and at the crossing of the embankment base boundary line - 54.0 kts, i.e. much less than it was in the real case.

e) In view of the above statements the basic difference between normal landing with the stop on the runway and the being analysed sequence of events on 14 September 1993 in Warsaw was the significantly greater - in compare to the Operations Manual indications - ground speed at the moment of touchdown, resulting in the significant (in the range of 40%) extension of the rollout distance, as well as the point of full touchdown.

[1] Values taken from Airplane Operations Manual AOM 320A.

[2] Values calculated from the data given in AOM 320A.

[3] Values read from the flight data recorder.

3. Conclusions

3.1 Findings

A. Weather and meteorological information

1: At the moment of the aircraft landing the front accompanied by heavy rain and windshear was passing the airfield. Two aircraft that landed earlier than DLH 2904 reported to air traffic services the windshear at the final approach to RWY 11. The landing of DLH 2904 was being carried out in full visibility of the aerodrome.

2: The meteorological information ATIS for the Okecie airport broadcasted in the period which preceded landing of the DLH 2904 aircraft, as well as that broadcasted in the post-crash time, were giving wind information based on averaged values and comprised the NOSIG code. It meant that no significant changes of weather were anticipated for the next two hours. The same information was transmitted to the ATS monitors.

3: Aeronautical Information Publication (AIP) Poland, Vol.1, Met 03 (dated 11 JAN 90) clears out some deviations from the Annex 3 to the ICAO Convention (Chicago) in respect of

limitations of the meteorological services level. This information is still available through the AIP to all users of the Polish airspace.

B. Aircraft

1: The aircraft was serviceable and all its basic documents were up-to-date and valid.

2: The aircraft was loaded within its operational limits.

3: The aircraft automatics comprises, for basic landing configuration if the aircraft (i.e. with flaps extended to FULL position), the programme which subjects actuation of all braking devices to some specific conditions. Ground spoilers, when selected, will extend provided that either shock absorbers are compressed at both main landing gears (the minimum load to compress one shock absorber being 6300 kgs), or wheel speed are above 72 kts at both main landing gears. Engine reversers, when selected, will deploy provided that shock absorbers are compressed at both main landing gears. Such a logic results in the lack of possibility of immediate actuation of two mentioned above aircraft's braking devices without meeting the conditions described.

4: In emergency, the crew is unable to override the lock-out and to operate ground spoilers and engine thrust reversers.

5: Depth of grooves on tyre tread at three wheels of the main undercarriage was considerably decreased. At very high touchdown speed it could facilitate progressive building of conditions conducive to slippage.

C. Aircraft Manuals

1: Lufthansa Flight Crew Manual on pages 6.60/5 and 6.60/6 gives the procedures for the case of windshear. According to this manual "If the disposed landing distance allows, the speed may be increased maximum by 20 kts. This increased speed should be maintained until flare-out". However the FLIGHT CREW OPERATING MANUAL for A320/321 issued by AIRBUS INDUSTRIE in Section 3.04.91 on page 3 allows to increase the approach speed by 15 kts, and besides in AIRBUS INDUSTRIE COMMENTS ON FINAL REPORT RELATING TO A320 D-AIPN ACCIDENT AT WARSAW SEPTEMBER 14TH 1993 on the page 6 warning is expressed against maintaining this excessive speed by touchdown.

2: It is to be noted, that operators Flight Crew Manual contains on the page 6.60/6 the notice that the excessive touchdown speed may extend the rollout distance by about 25%, but in performance information of the Manual, on the tables of required landing distances there is no notice on the methods to be used to determine the real landing (and rollout) distance when landing with the increased speed - according to the Manual - even by 20 kts in case of windshear (see AOM 320A, Vol. II, Page 5.24/18). On the other hand the AOM manual specifies how to calculate corrections to these distances in regard to much less important factors as e.g. difference in pressure altitude, aircraft icing or automatic landing.

D. Crew

1: The crew did not notice on the weather radar screen in the course of approach the atmospheric front between their position and the aerodrome, and achieving visual contact with the aerodrome they switched the radar off. The front had been noticed on their weather radar screen by the crew of Jet Aviation having landed just before DLH 2904.

2: The crew decided to land without use of automatic wheel braking system.

3: There was no reaction of the flight crew to the tailwind demonstrated by

- clearly visible difference between Air Speed and Ground Speed in the course of approach,

- wind vector on EFIS during final approach, although the change of direction and velocity of wind was commented upon in the crew's conversation.

4: The pilot at the controls (PF) decided to land (with approval of the pilot in command) without being warned by him (according to the suggestion of AOM A320, Vol. II, page 5.24/18) of tailwind components considerably exceeding the operational limit of 10 knots.

5: Landing was continued in spite of excessive tailwind component, excessive ground speed and the touchdown point moved considerably ahead (towards the runway end), while abandonment of landing and go around was justified and still feasible.

6: The steering technique applied in the course of aircraft landing in the touchdown phase utilized the lateral bank as a countermeasure to balance lateral wind component. It resulted in touchdown on one main undercarriage leg only and a false impression on the part of the crew that touchdown was efficient. In reality the immediate start of operation of braking devices was not possible.

7: In the light of recommendations of the AOM manual, Vol. II, Page 5.24/18 the co-operation between pilots was incorrect (probably as a result of non-typical crew composition). The pilot performing the check has allowed too wide margin of independence to the checked pilot.

E. Aerodrome

1: As a result of pertaining precipitation the runway was covered with uneven layer of water of the thickness difficult to define.

2: There is embankment with the LLZ aerial located at the extension of RWY 11, 100m from its end (i.e. 3% of the total RWY 11 length) and on the runway centreline. This embankment is not described in AIP.

F. ATC services

The TWR personnel did not have at hand the certified data on current direction and velocity of the surface wind. Data received from meteorological services were delayed.

G. Evacuation

Passengers were leaving the aircraft by themselves, assisting each other. Two of four cabin attendants, who did not suffer major injuries in the crash, opened the doors, actuated escape slides, directed passengers to exits as well as helped wounded persons to leave the fire-endangered zone. Unsuccessful was an attempt to save one of the wounded passengers and to evacuate the body of the dead pilot-in-command.

H. Extinguishing the fire

In less than three minutes after the emergency call the column of five fire-fighting vehicles reached the crash site and their crews efficiently extinguished the external fire. For the reason, however, due to fire character (aviation fuel and oxygen escaping from on board systems) and violent fire expansion inside the aircraft extinguishing of fire in this area became possible only

after the explosion has destroyed part of the cabin roof and fire extinguishing agents could be delivered through the produced hole.

3.2 Causes of the accident

Cause of the accident were incorrect decisions and actions of the flight crew taken in a situation when the information about windshear at the approach to the runway was received. Windshear was produced by the front just passing the aerodrome; the front was accompanied by intensive variation of wind parameters as well as by heavy rain on the aerodrome itself. Actions of the flight crew were also affected by design features of the aircraft which limited the feasibility of applying available braking systems as well as by insufficient information in the aircraft operations manual (AOM) relating to the increase of the landing distance.

4. Recommendations

4.1 For operator

4.1.1: The aircraft operational manual AOM A320A, Vol. II, page 11.70/3 and VOL II, page 8.20/8 Chapter "Supplementary Procedures" should be complemented with corrections to the landing distance in case of the landing approach at speed increased for the reason of windshear.

4.2 For A320 aircraft manufacturer

4.2.1: Possibility should be analysed to introduce the emergency use of ground spoilers and thrust reversers independently of meeting the criteria imposed by aircraft logics.

4.2.2: The possibility should be considered to modify the thrust reverser system to enable use of more than 71% N1 in the emergency.

4.3 For Polish Civil Aviation Authorities

4.3.1: The system of collecting and distributing meteorological information should be adapted to the level equal to recommendations of Annex 3 to the ICAO Convention (Chicago).

4.3.2: The embankment with the new LLZ aerial near the end of RWY 11 should be

described in the AIP Poland.